ISS and Human Research Project Office Highlights
October 16, 2009

ISS Research Program

Atomic Oxygen Erosion Yield Predictive Tool Developed Based on Materials International Space Station Experiment (MISSE) Flight Data.

An atomic oxygen erosion yield predictive tool that estimates the low Earth orbit atomic oxygen erosion yield of polymers has been developed based on the results of the MISSE 2 Polymer Erosion and Contamination Experiment (PEACE) Polymers experiment. The predictive tool utilizes the chemical structure, atomic populations of the polymer repeat unit, oxygen bonding information, and physical properties (such as density and ash content) that can be measured in ground laboratory tests. The tool has a correlation coefficient of 0.895 when compared with actual MISSE 2 PEACE Polymers space data (for 38 polymers and pyrolytic graphite). This predictive tool allows one to make reasonable estimate the atomic oxygen durability of polymers and composites without requiring lengthy in-space testing. A paper entitled “Atomic Oxygen Erosion Yield Prediction for Spacecraft Polymers in Low Earth Orbit” by Bruce Banks (RES/NASA-Alphaport), Jane Backus (RES/Ohio Aerospace Institute), Michael Manno (Alphaport), Deborah Waters (RES/Arctic Slope), Kevin Cameron (RES/OAI) and Kim de Groh (RES) has been published as NASA TM-2009-215812. The paper was presented at the 11th International Symposium on Materials in Space Environment (ISMSE-11), held September 15-18 in Aix en Provence, France, and the paper will be included in the conference proceedings, to be published soon. This work is supported by the International Space Station Research Project. (POC: RES/Bruce Banks, (216) 433-2308))

Analysis of the Materials International Space Station Experiment 5 (MISSE 5) Polymer Film Thermal Control Experiment.

Post-flight experiment research has been conducted on the MISSE 5 Polymer Film Thermal Control Experiment documenting the change in tensile strength and percent elongation of some typical polymer films (11 different types both as-received and coated to block erosion by atomic oxygen) exposed in a nadir facing environment on the International Space Station. The data has been compared, where possible, to similar ram and wake facing experiments flown on MISSE 1 to get a better indication of the role the different environments play in mechanical property change. The majority of the polymer film tensile test samples flown on MISSE 5 experienced some loss in tensile or yield strength and percent elongation as a result of exposure to the environment. There was also some indication that texture due to atomic oxygen erosion may give rise to stress points on the surface that cause the samples to break at a lower peak load. Comparing MISSE 1 and MISSE 5 test results for coated Teflon FEP (fluorinated ethylene propylene) and coated Upilex S indicated that there is an environmental exposure dependence on ultraviolet radiation, ionizing radiation or the number of thermal cycles for % loss in elongation. The levels at which changes occur, and which environment factor or combination of factors causes these changes is unclear and needs further investigation in experiments where these factors can be controlled or eliminated independently. A paper on this research entitled “Space Environment Exposure Results from the MISSE 5 Polymer Film Thermal Control Experiment on the International Space Station” by Sharon K.R. Miller, and Joyce A. Dever has been presented at the 11th International Symposium on Materials in Space Environment (ISMSE-11), held

September 15-18 in Aix en Provence, France, and the paper will be included in the conference proceedings, to be published soon. This work is supported by the International Space Station Research Project. (POC: RES/Sharon Miller, (216) 433-2219).

Materials International Space Station Experiment (MISSE) Post-Retrieval Analysis of Optical and Thermal Properties.
Optical and thermal properties were measured for the MISSE 2 Polymer Erosion and Contamination Experiment (PEACE) Polymers experiment samples and the MISSE 2 & 4 Spacecraft Silicone experiment samples after long-term space exposure on the ISS. The majority of the PEACE Polymer samples were comprised of numerous thin film layers stacked together. Because the MISSE 2 mission was much longer (3.95 years) than planned (1.5 years), one sample was completely eroded away (PBI) and numerous other samples were severely degraded. Therefore, optical and thermal measurements could not be obtained on all samples. The optical properties of 43 samples, and thermal properties of 40 samples, were obtained and compared to control samples. Several trends were observed in the data. For most samples, the reflectance and transmittance characteristics changed greatly upon directed low Earth orbit atomic oxygen exposure due mainly to the development of surface texturing. Because many of the PEACE polymers and the DC 93-500 silicones are commonly used for spacecraft applications, knowledge of potential changes in their optical and thermal properties with long term space exposure is very important. A paper entitled "Changes in Optical and Thermal Properties of MISSE 2 PEACE Polymers and Spacecraft Silicones" by Deborah Waters (RES/ASRC), Kim de Groh (RES), Bruce Banks (RES/Alphaport) and Kevin Cameron (RES/OAI) summarizes the MISSE 2 PEACE Polymers and Spacecraft Silicones experiments, the specific materials flown, optical and thermal property measurement procedures, and the optical and thermal property data are presented in both tabular form and spectral data. This paper was presented at the 11th International Symposium on Materials in Space Environment (ISMSE-11), held September 15-18, 2009 in Aix-en-Provence, France, and will be included in the conference proceedings when published. This research is supported by the International Space Station Research Project. (POC: RES/ Deborah Waters (216) 433-5371)

Erosion Morphology Studies of Materials International Space Station Experiment (MISSE) Flight Samples.
Forty-one polymer samples, collectively called the Polymer Erosion and Contamination Experiment (PEACE) Polymers, were exposed to ram atomic oxygen on the exterior of the International Space Station (ISS) for nearly four years as part of MISSE 2. The PEACE polymers were typically in thin-film form (25 to 500 μm thick) and depending on the polymer thickness and estimated erosion yield, stacking of numerous thin film sample layers was often necessary. Erosion morphology studies have been conducted on nine MISSE 2 PEACE samples, along with aluminized-fluorinated ethylene propylene (Al-FEP) also flown on MISSE 2. Erosion cone structures, which typically develop during ram atomic oxygen erosion of materials (like polymers) with gaseous oxidation species, were examined for high and low erosion yield samples. Also studied were the erosion characteristics of thin film polymers eroded through several layers. This information is relevant to the durability of materials and components on spacecraft that are protected by thin film polymers. Examination of the flight samples by field emission scanning electron microscopy (FESEM) and energy dispersive spectroscopy (EDS) was found to provide a wealth of knowledge on the degradation of thin film polymers in the LEO

space environment. For example, erosion can occur in underlying materials below thin film polymers, even when the film is still structurally intact. Therefore, a spacecraft may have damage to underlying layers on-orbit, even if the erosion yield (Ey) predicts that the "outer layer" will be intact. Also, atomic oxygen erosion cone propagation in multi-layered polymer films can result in the generation of weakly attached free particles, which could result in particulate contamination on-orbit. The results have been summarized in a paper entitled "MISSE 2 PEACE Polymers Erosion Morphology Studies" by Kim de Groh (RES) and Bruce Banks (RES/Alphaport). This paper was presented at the 11th International Symposium on Materials in Space Environment (ISMSE-11), held September 15-18, 2009 in Aix-en-Provence, France. The paper will be included in the conference proceedings when published. This work is supported by the International Space Station Research Project. (POC: RES/Kim K. de Groh, (216) 433-2297)

Flow-Boiling Experiment discussed with grant recipient at Purdue University.
M. Hasan/RET, B. Motil/RET and N. Hall/MAH traveled to the Purdue University on October 7, 2009 to meet with Professor Issam Mudawar of the Mechanical Engineering Department to discuss the progress of a NASA funded ground based grant awarded to Professor Mudawar. The discussion focused on the design of a two-phase flow loop that can be made to fit in the existing test facilities on the ISS to perform flow boiling and flow condensation experiments. The discussion led to the preparation of a white paper that was submitted to the National Research Council Decadal Survey on Biological and Physical Sciences in space. They attended senior students' presentation on flow boiling test loop design.

Nancy Hall briefed the students about the research opportunities available to students at the Glenn Research Center. On October 8, 2009, Professor Steven Collicott of Aerospace Engineering gave them a tour of his 2-second Drop Tower test facility which is located within the new Neil Armstrong Hall of Engineering Building at Purdue University. The facility is utilizing an air bag mechanism and drag shield similar to our 2.2 second drop tower. (POC MAH/Nancy R. Hall, (216) 433-5643)

<u>Human Research Program</u>

Fifth Glenn Harness hardware verification review completed for ULF3 launch.
Hardware verification review for the fifth Glenn Harness was completed on October 8, 2009 for ULF3 launch, currently scheduled for November 12, 2009, in support of Harness Station Development Test Objective (SDTO). (POC: MAH/Gail Perusek, (215) 433-8729)